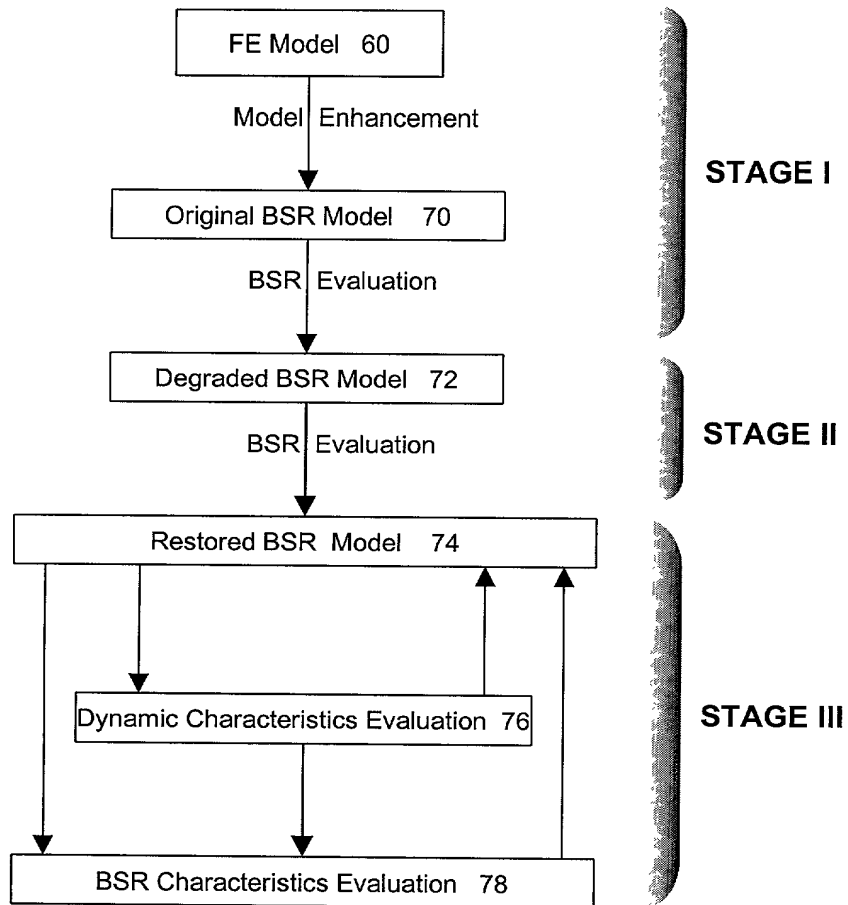


**Fig. 1**

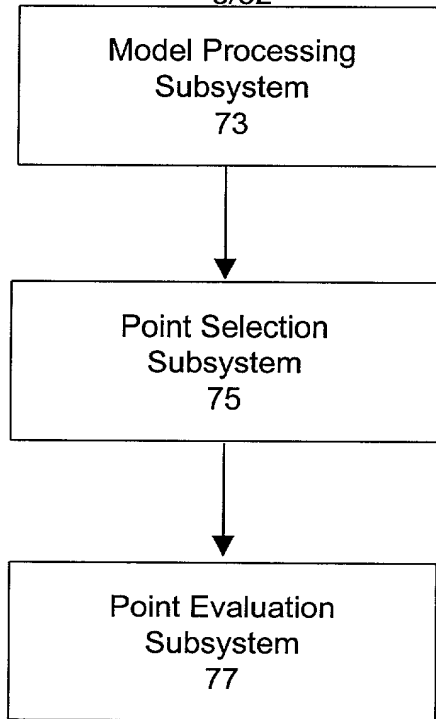


Enhanced fastener design      Improved Tolerance Control      Fastener maintenance schedule

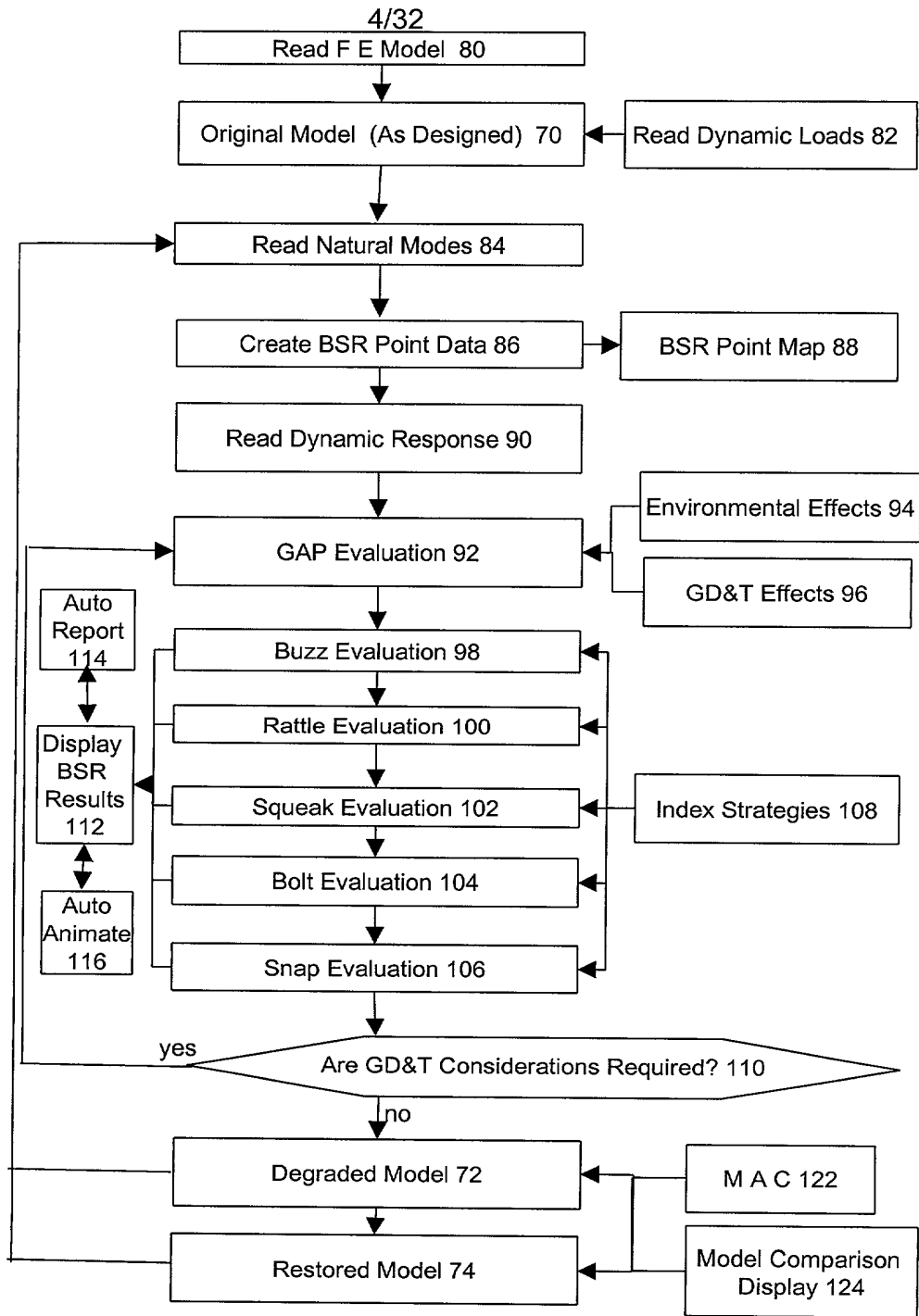
**Enhanced Product Design**

**Fig. 2**

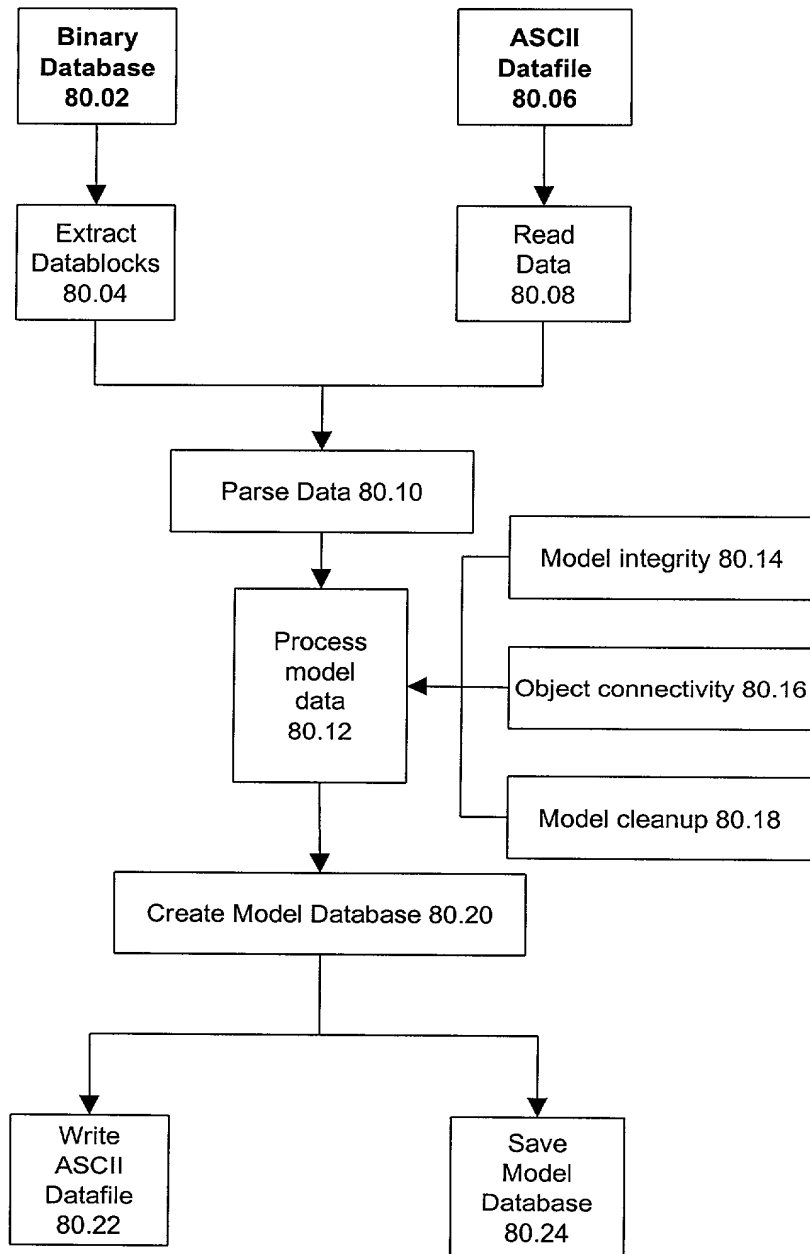
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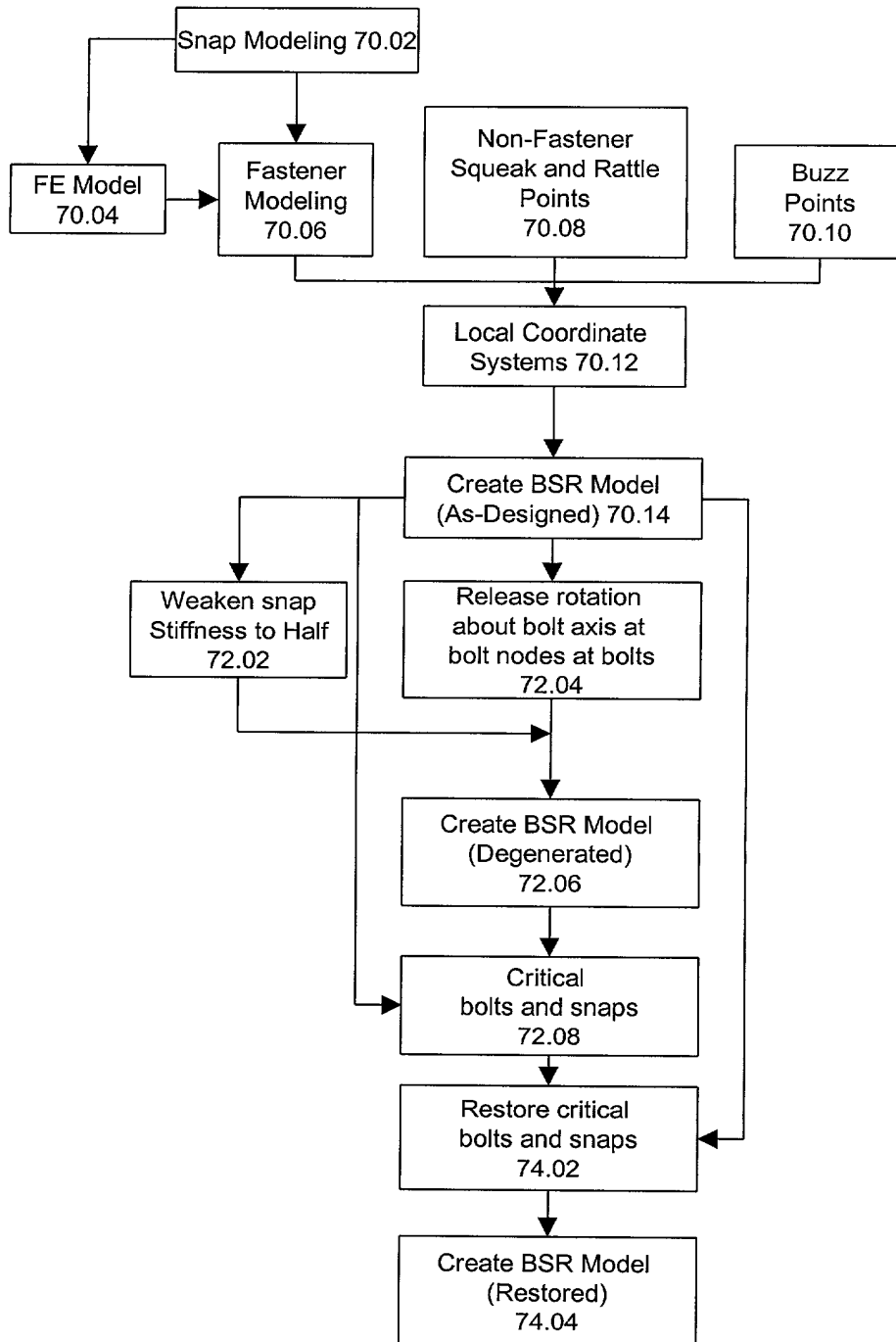


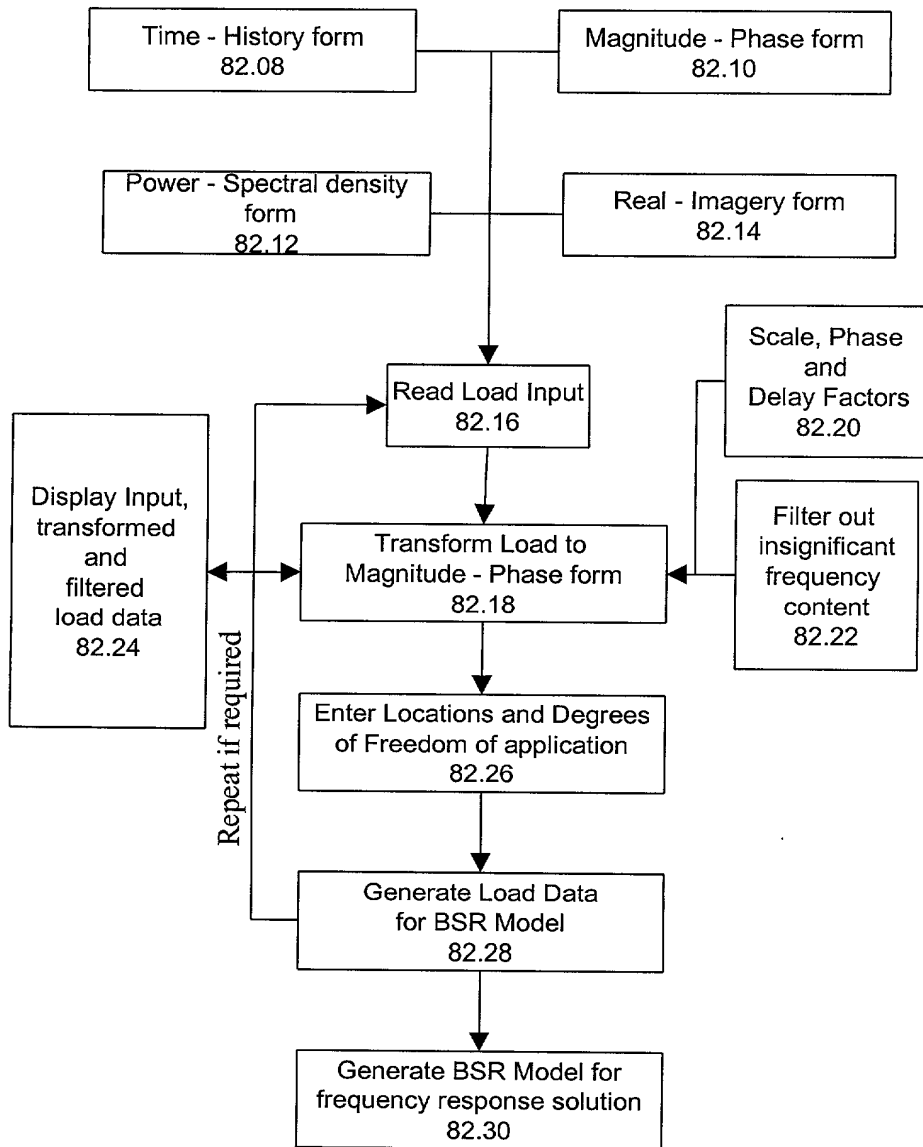
**Fig. 3**



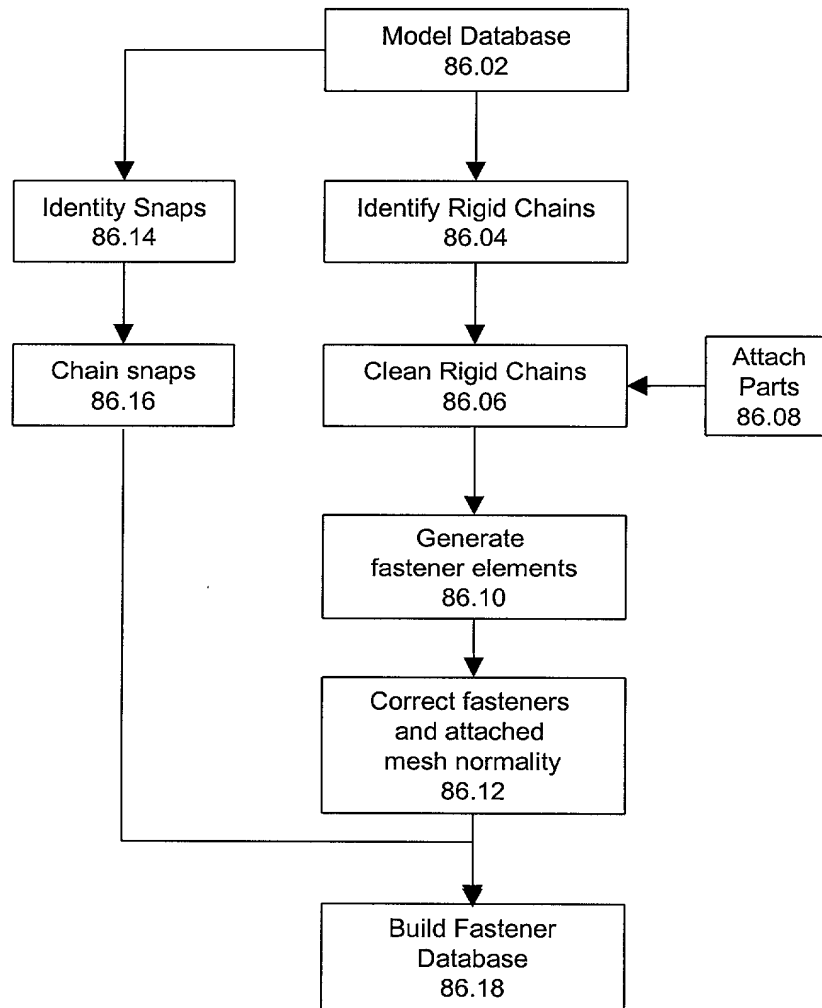
**Fig. 4**

**Fig. 5**

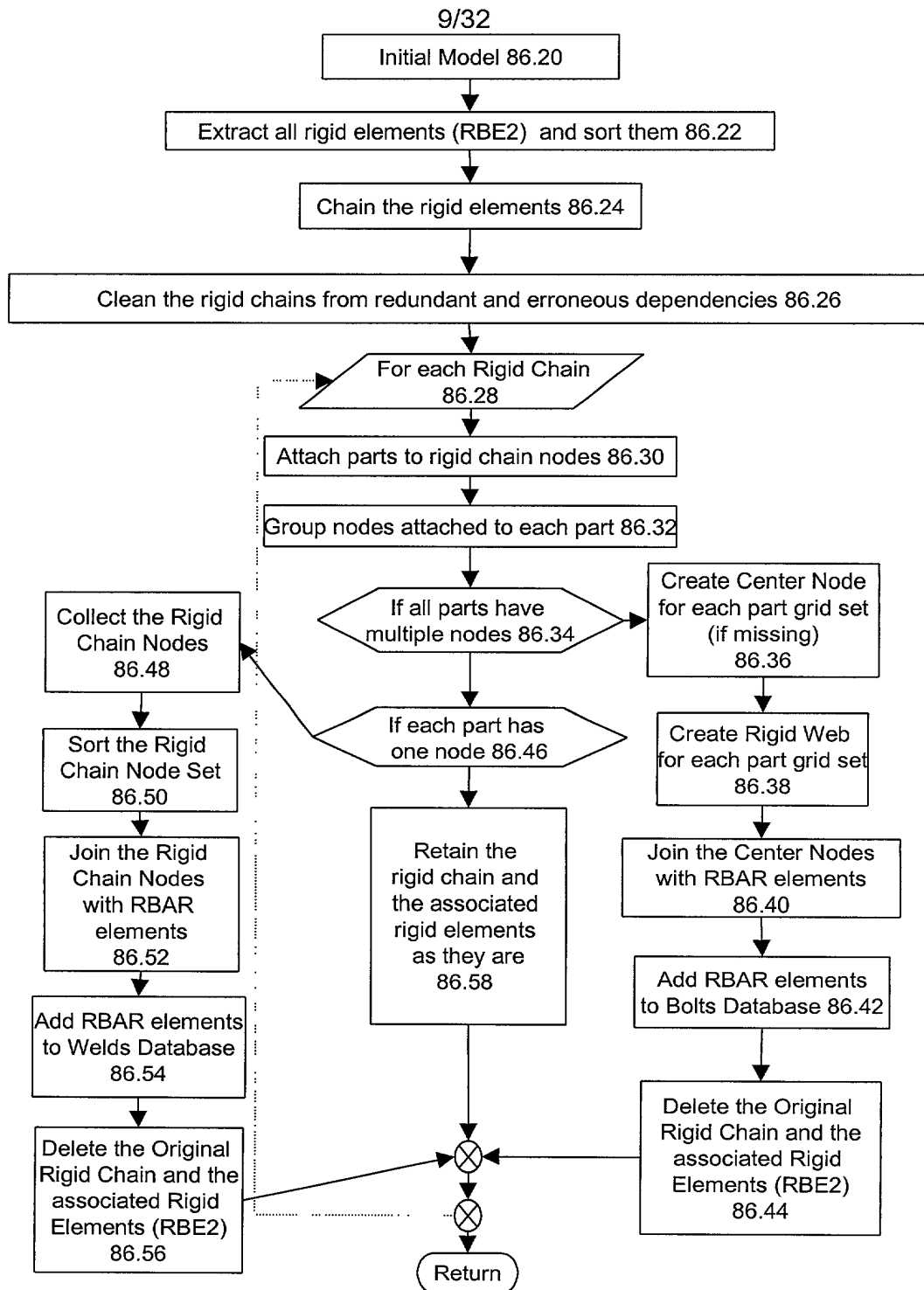
**Fig. 6**



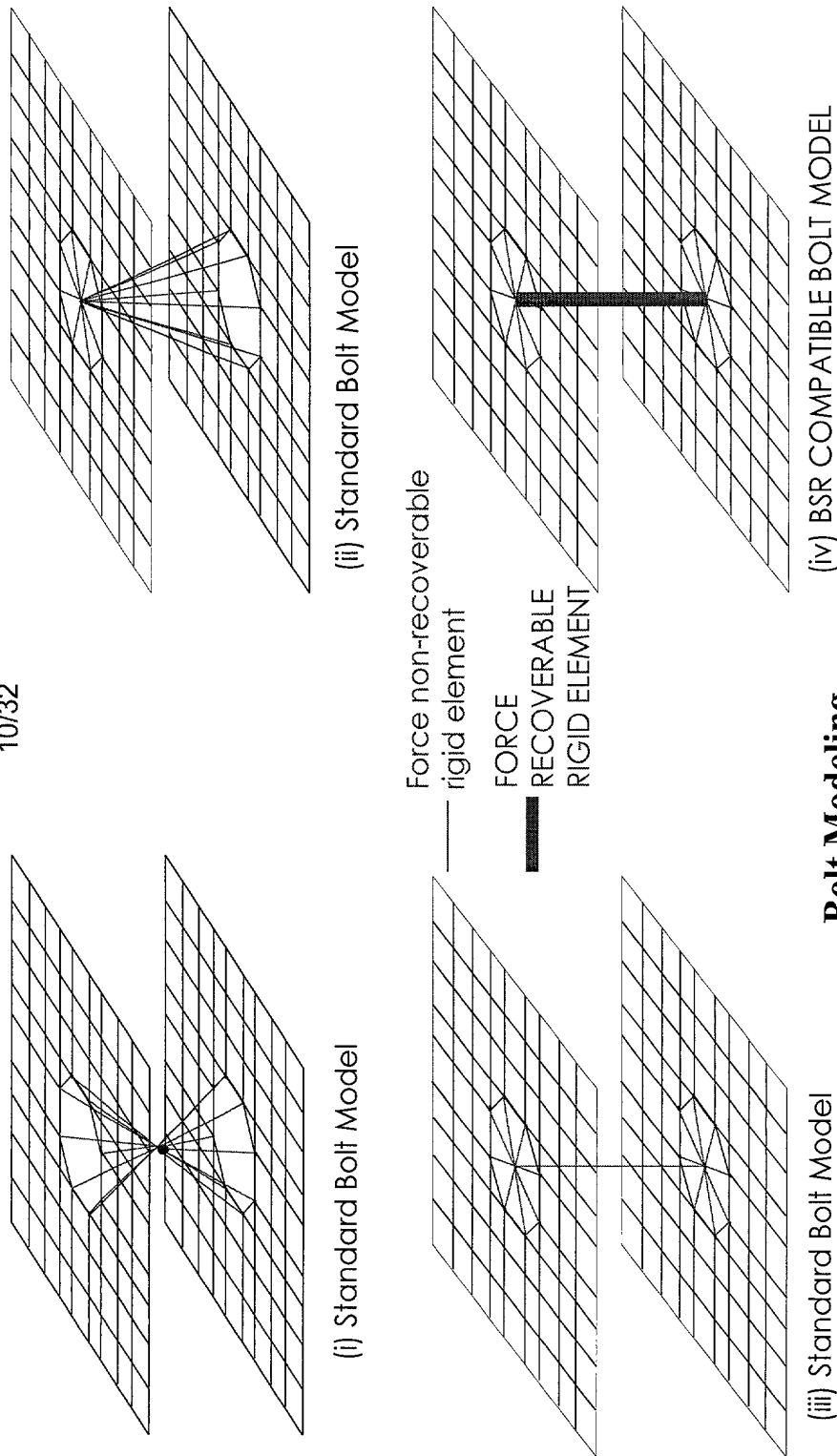
**Fig. 7**

**Fig. 8a**



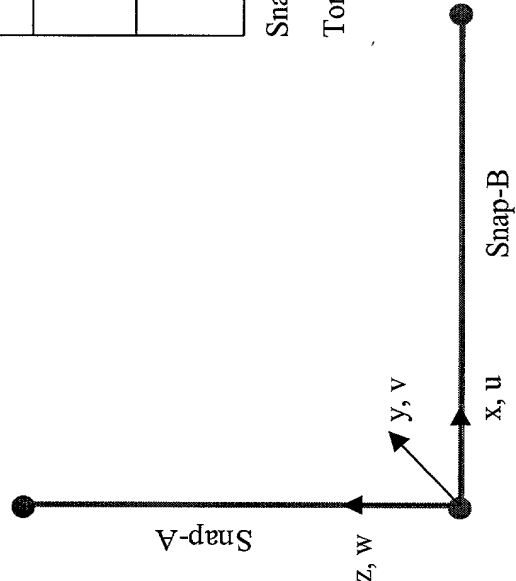


**Fig. 8b**



Bolt Modeling

Fig. 9a



	Rattle DOF	Squeak DOF
Snap-A	$w$	$u, v, \theta_z$
Snap-B	$u$	$v, w, \theta_x$

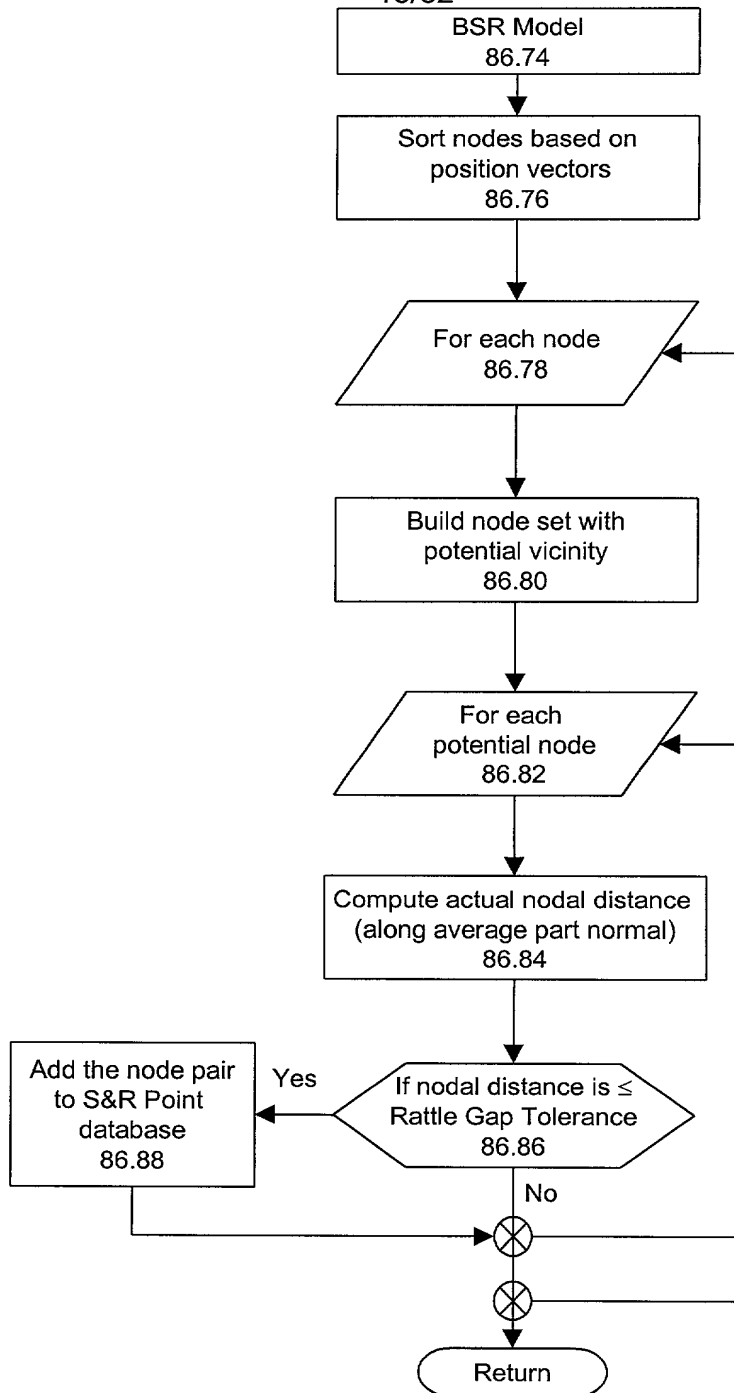
Snaps are identified with the spring elements (CELAS)

Torsion springs are ignored

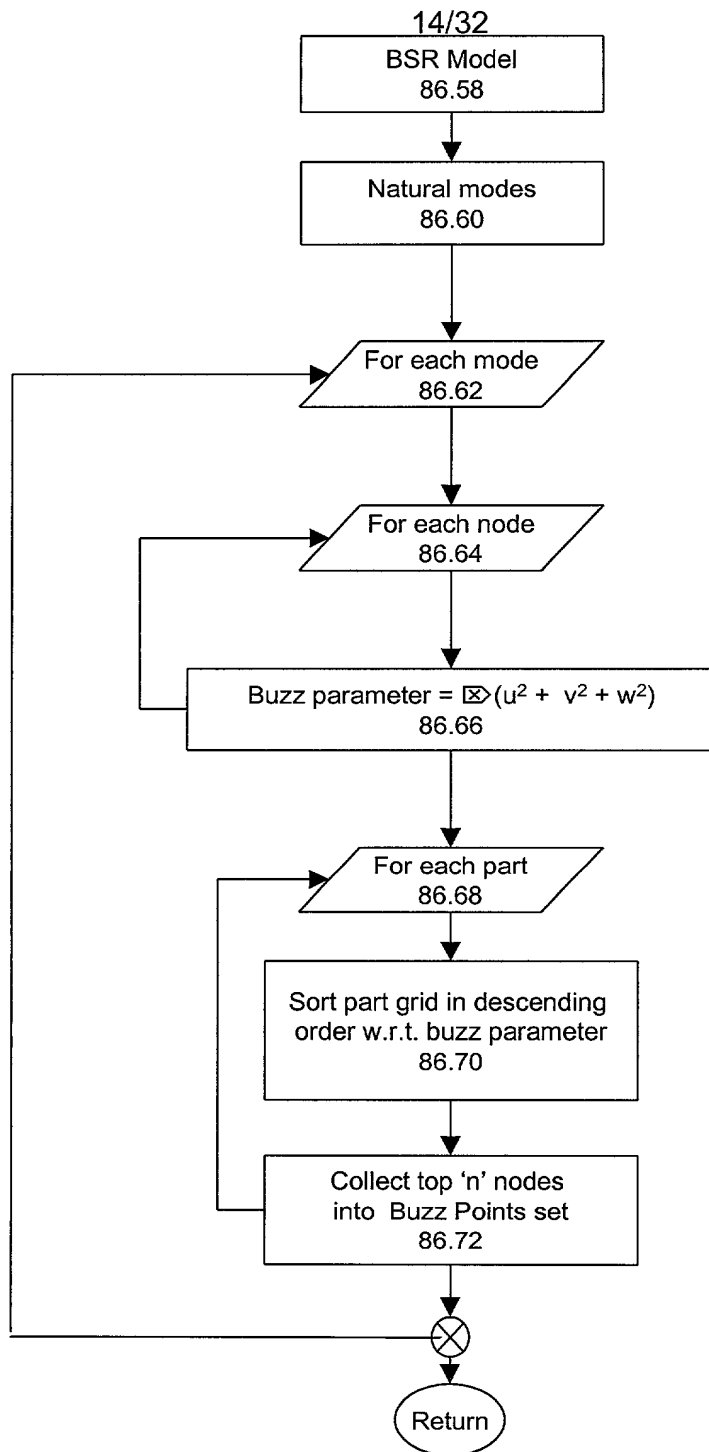
Snap Coordinate Compatibility  
**Fig. 9b**



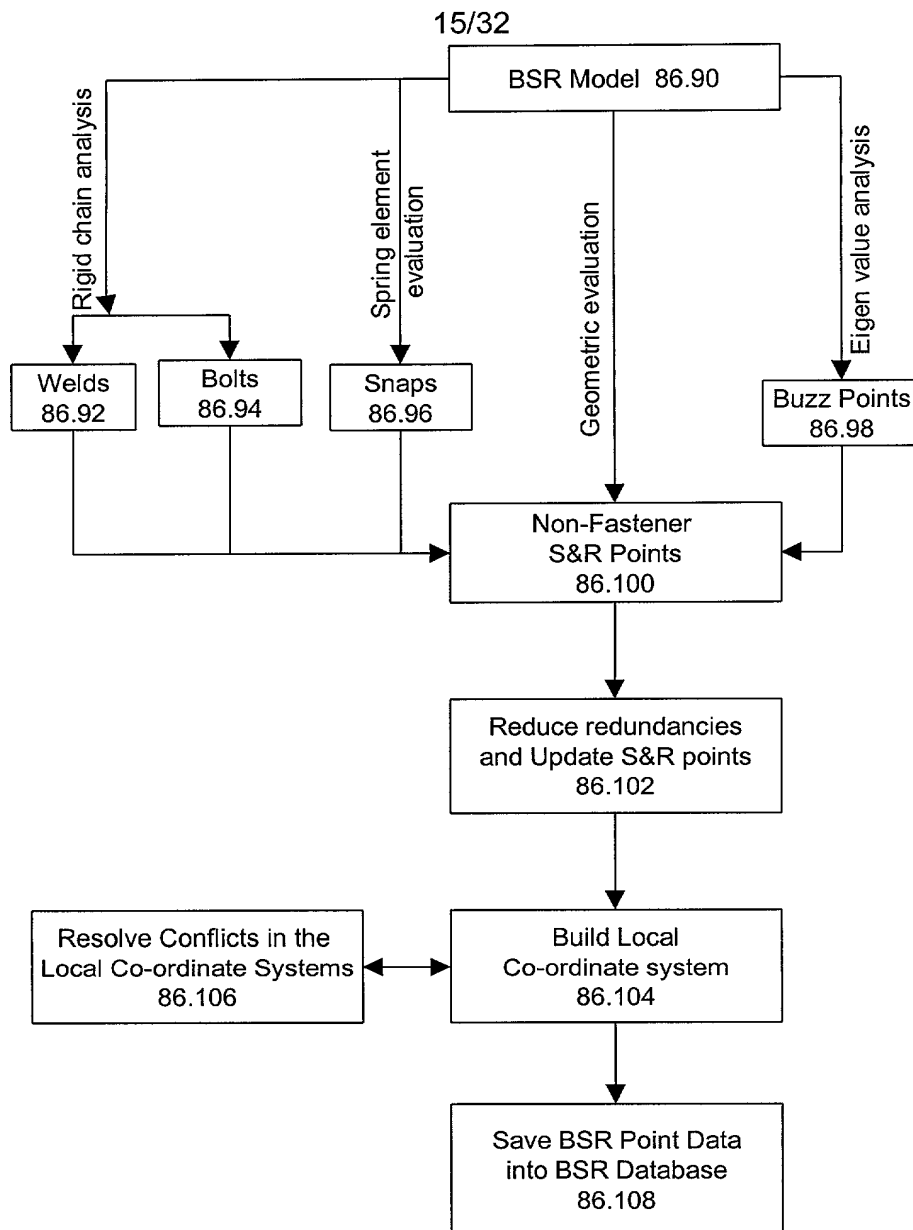
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**Fig. 9d**



**Fig. 9e**



**Fig. 9f**

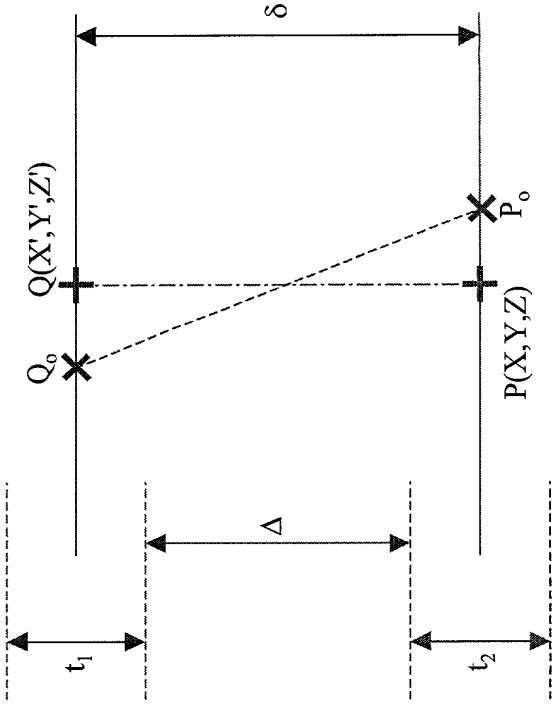
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P and Q are the points projected along the average part normal ( $\mathbf{n}_{avg}$ ) corresponding to the original points  $P_o$  and  $Q_o$ .

( $u_t, v_t, w_t$ ); ( $u'_t, v'_t, w'_t$ ) Displacements due to thermal effects  
 ( $u_h, v_h, w_h$ ); ( $u'_h, v'_h, w'_h$ ) Displacements due to moisture effects  
 ( $u_g, v_g, w_g$ ); ( $u'_g, v'_g, w'_g$ ) Displacements due to gravity effects

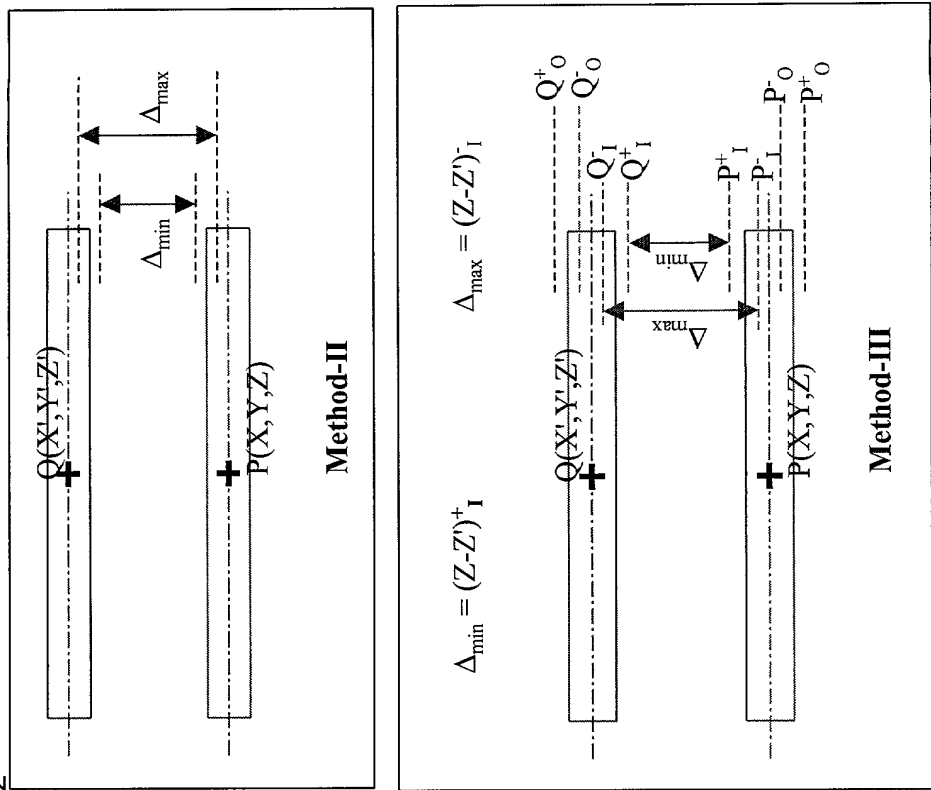
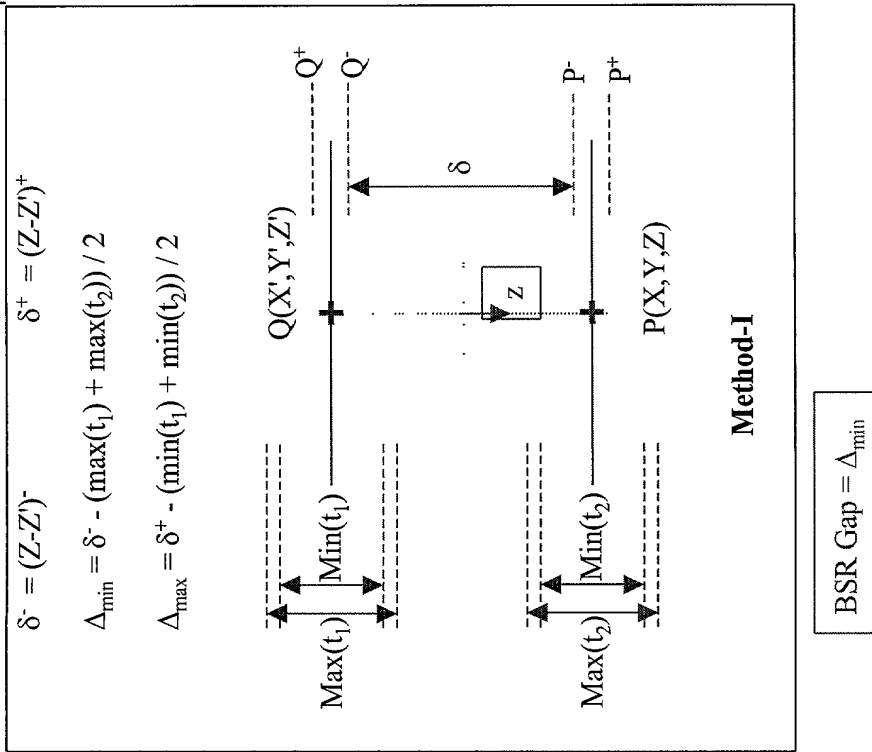
$$\begin{aligned} X &= x - u_t - u_h - u_g & X' &= x' - u'_t - u'_h - u'_g \\ Y &= y - v_t - v_h - v_g & Y' &= y' - v'_t - v'_h - v'_g \\ Z &= z - w_t - w_h - w_g & Z' &= z' - w'_t - w'_h - w'_g \end{aligned}$$

$$\begin{aligned} \delta &= \sqrt{(X-X')^2 + (Y-Y')^2 + (Z-Z')^2} \\ \Delta &= \delta - (t_1 + t_2)/2 \end{aligned}$$



Thickness and Environmental Effects  
**Fig. 10**

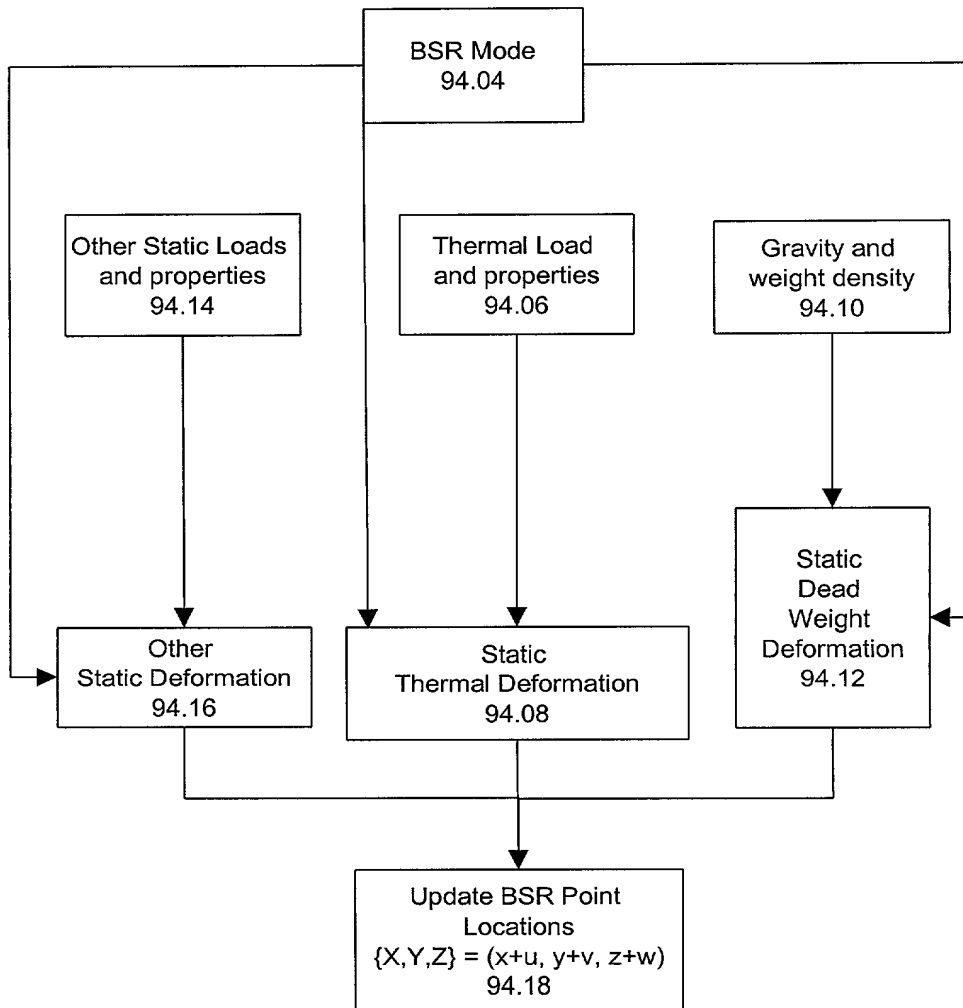




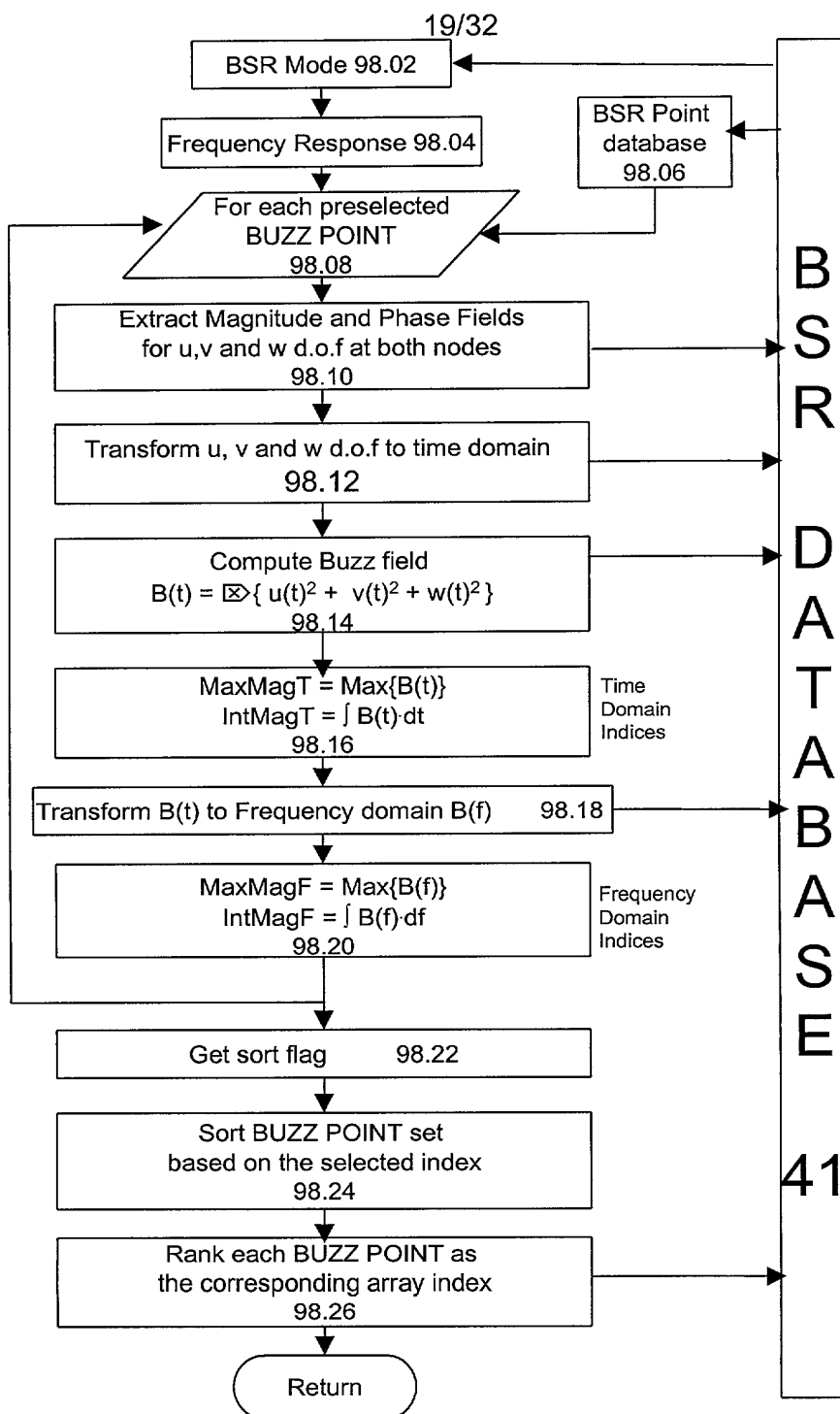
Note: P and Q are the projected points as in Fig 10

**Geometric Dimensioning & Tolerance Effects**  
**Fig. 11**

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**Fig. 12**



**Fig. 13**

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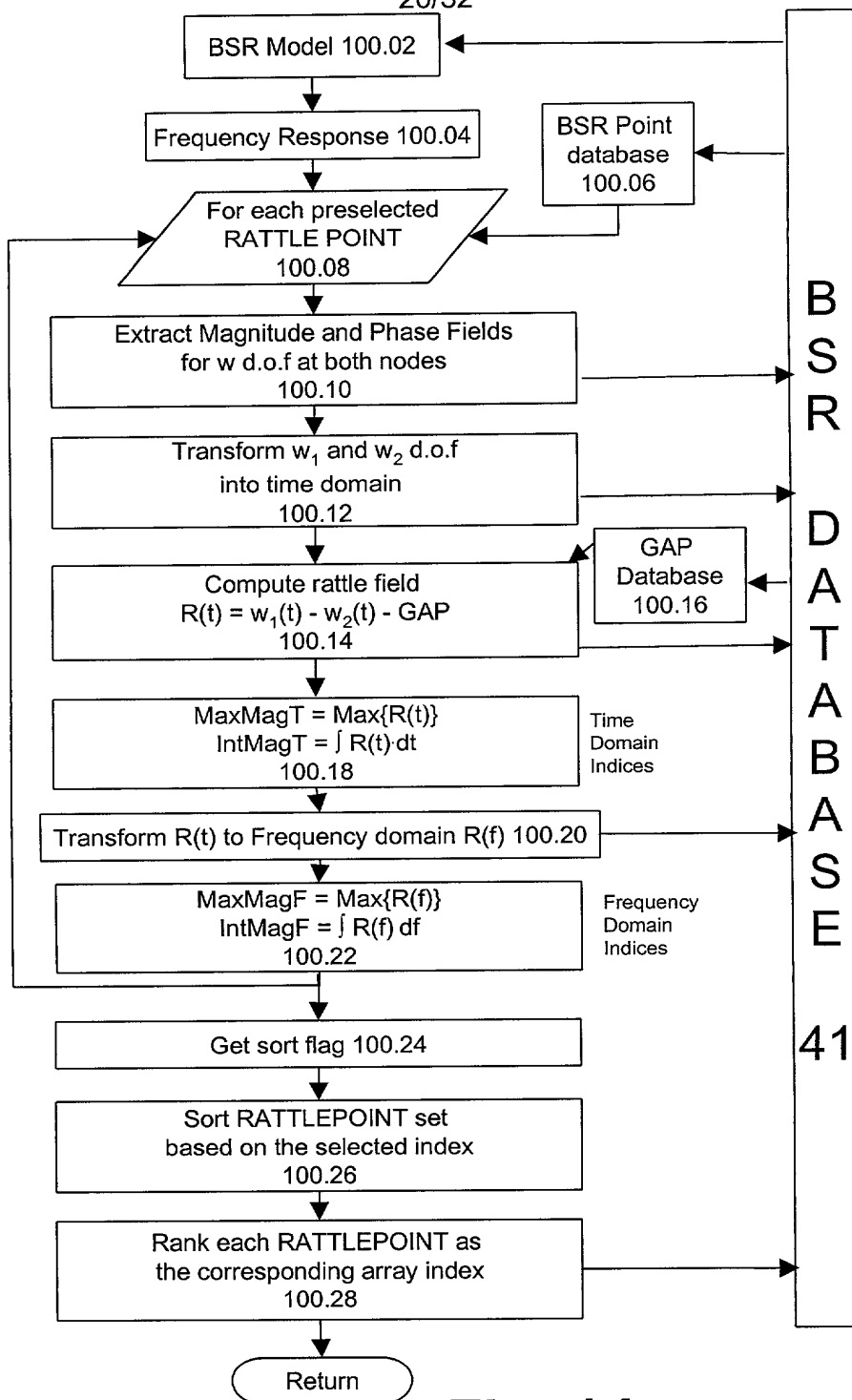
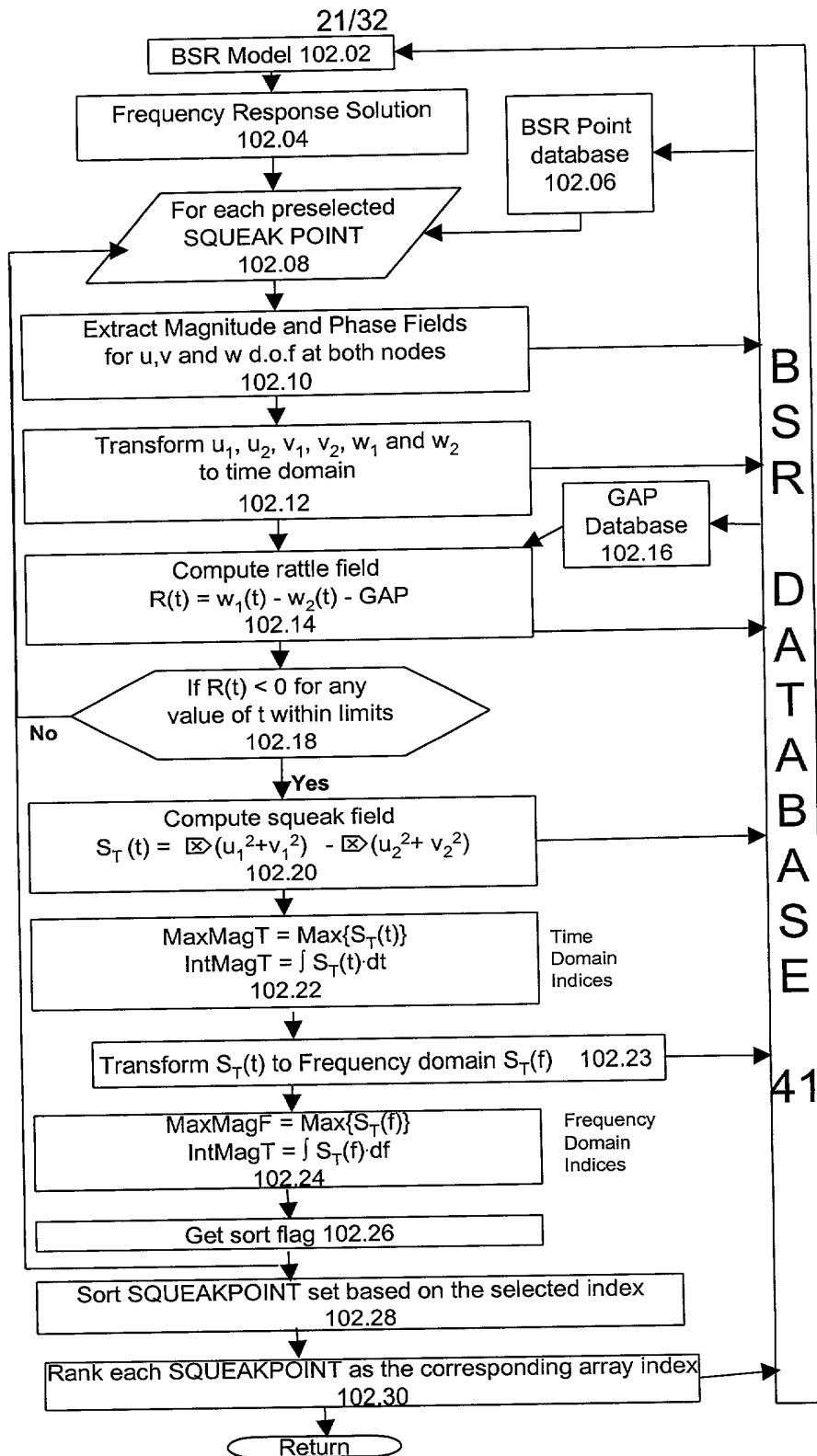
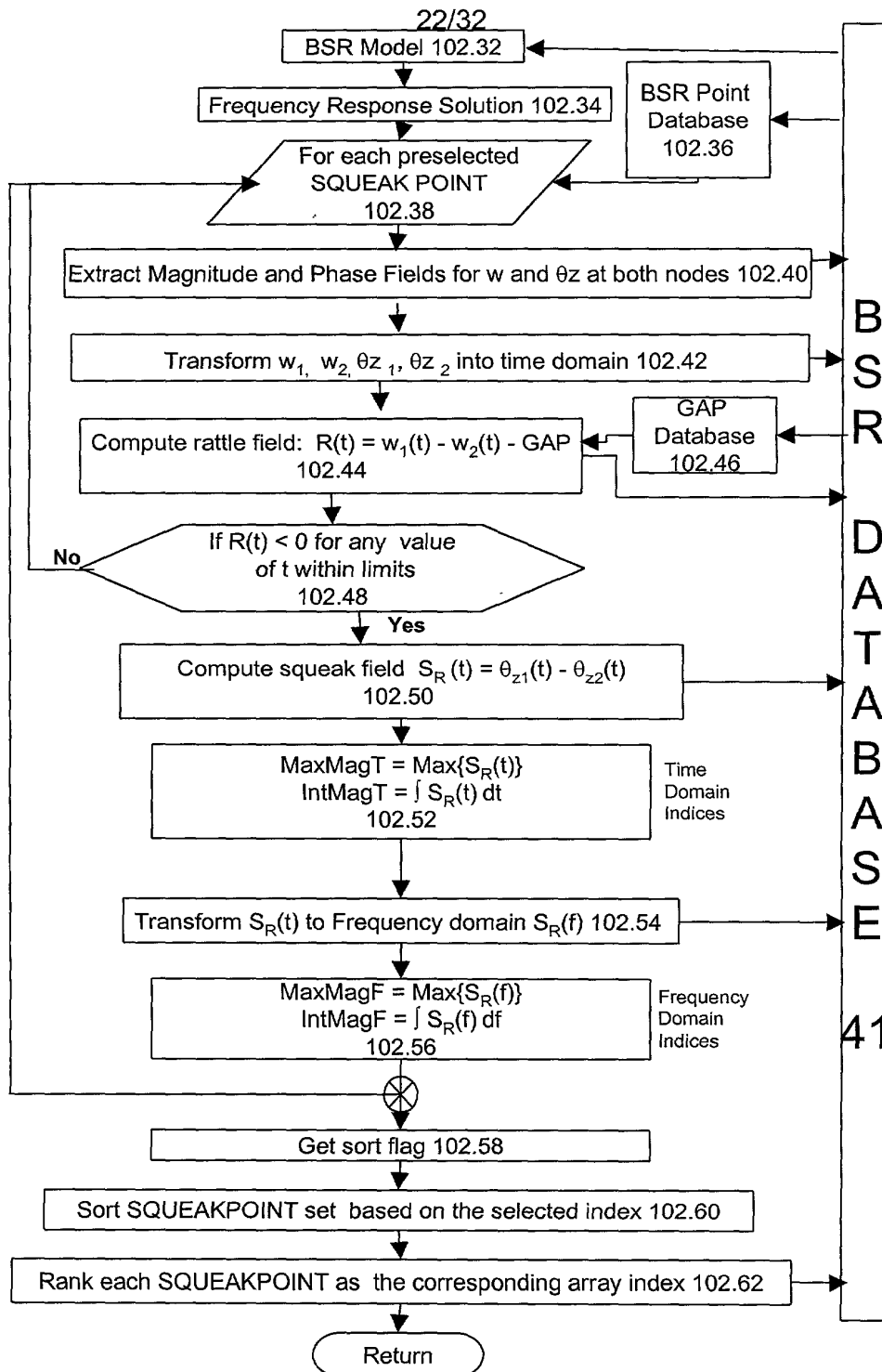
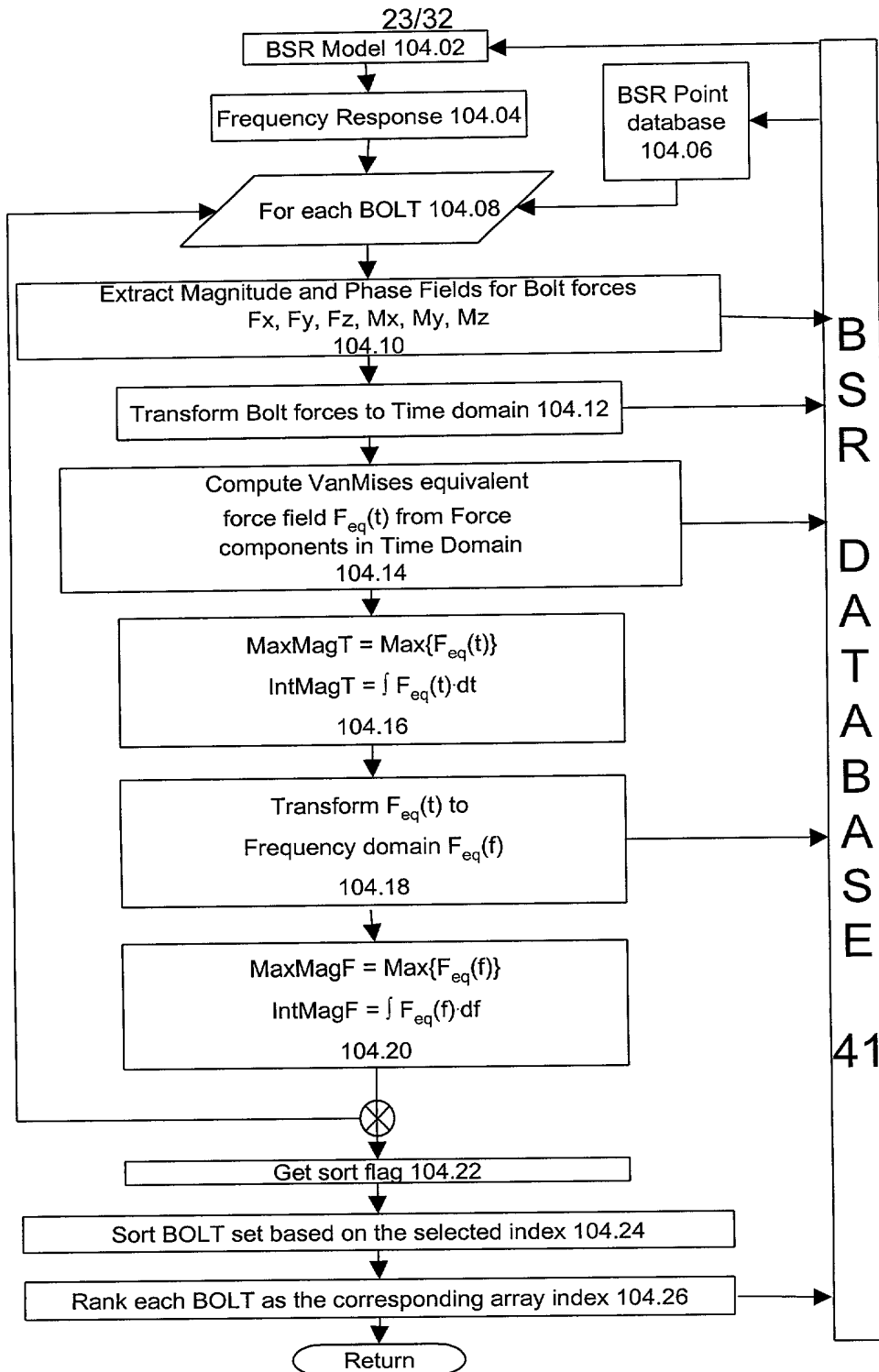


Fig. 14

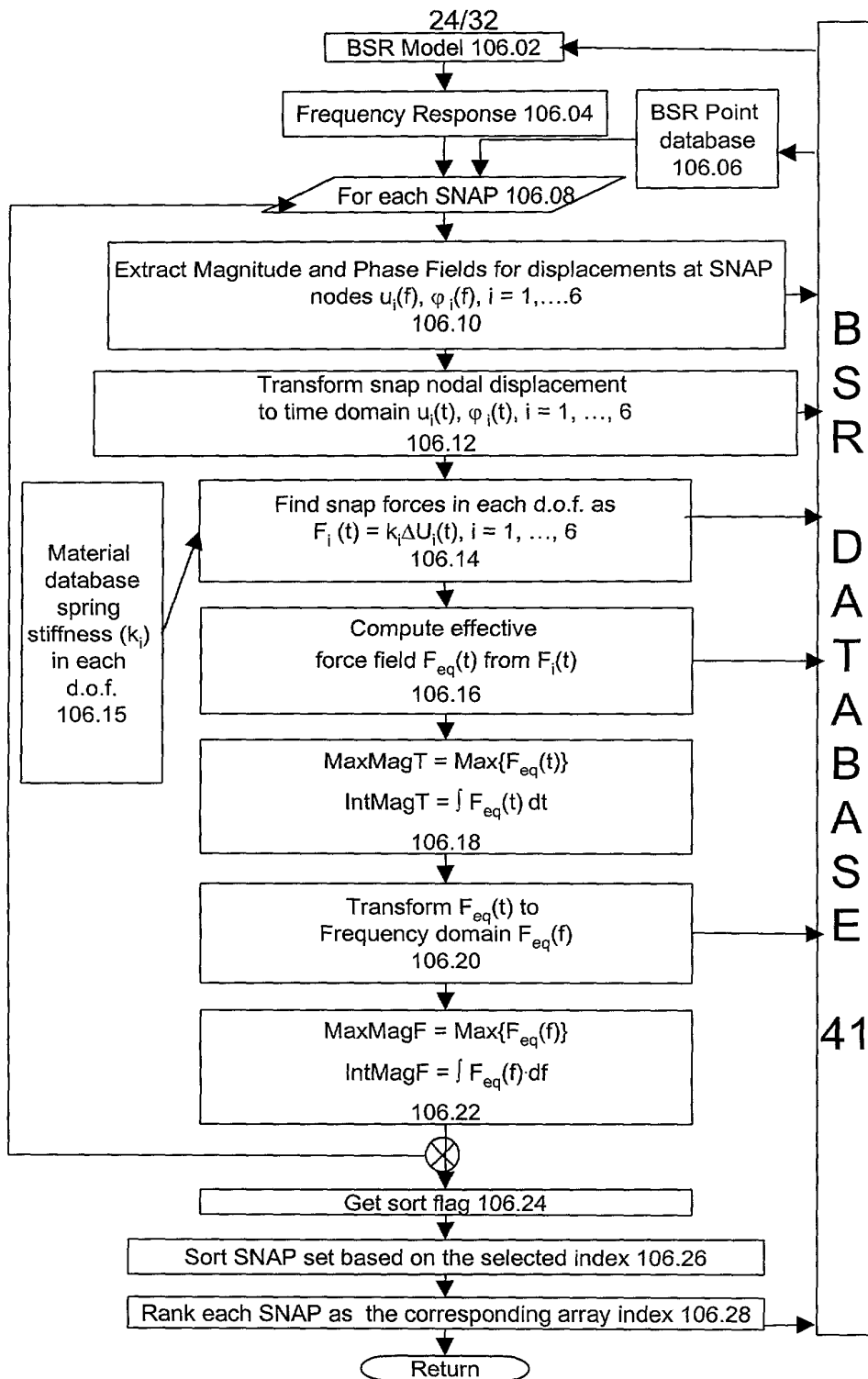




**Fig. 15b**

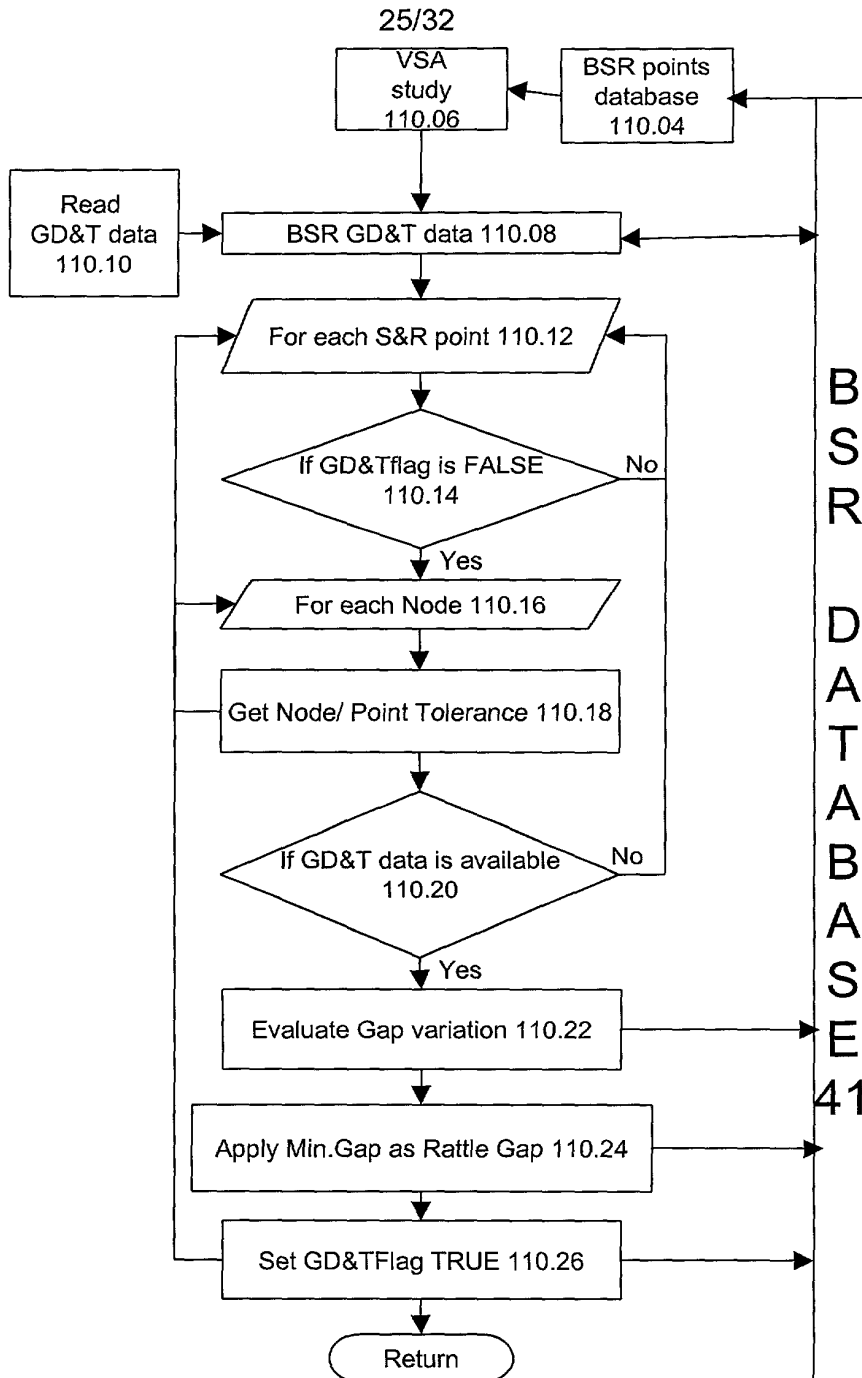


**Fig. 16**

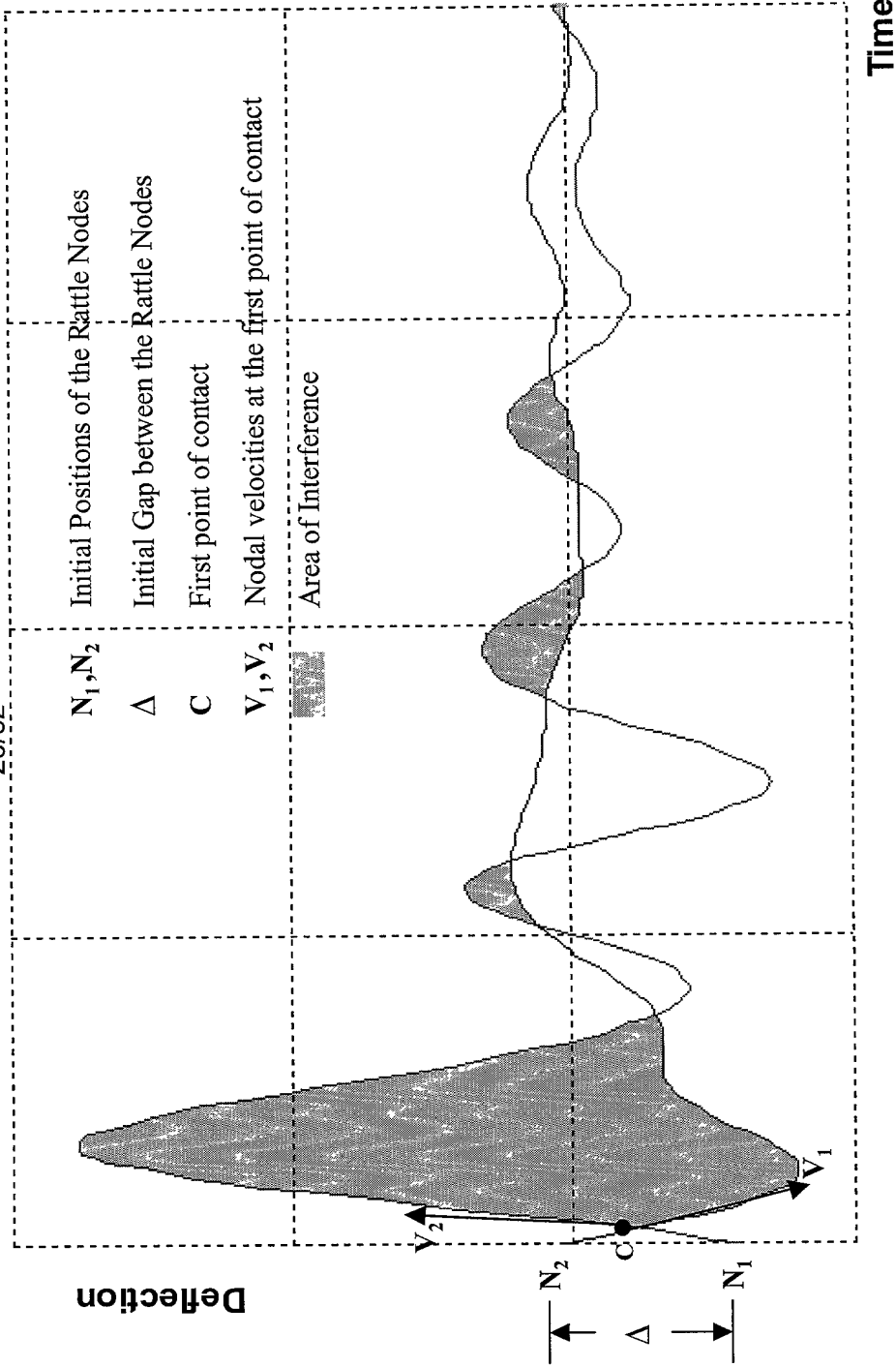


**Fig. 17**





**Fig. 18**



Area of Interference and Velocities of Approach at First Contact

Fig. 19

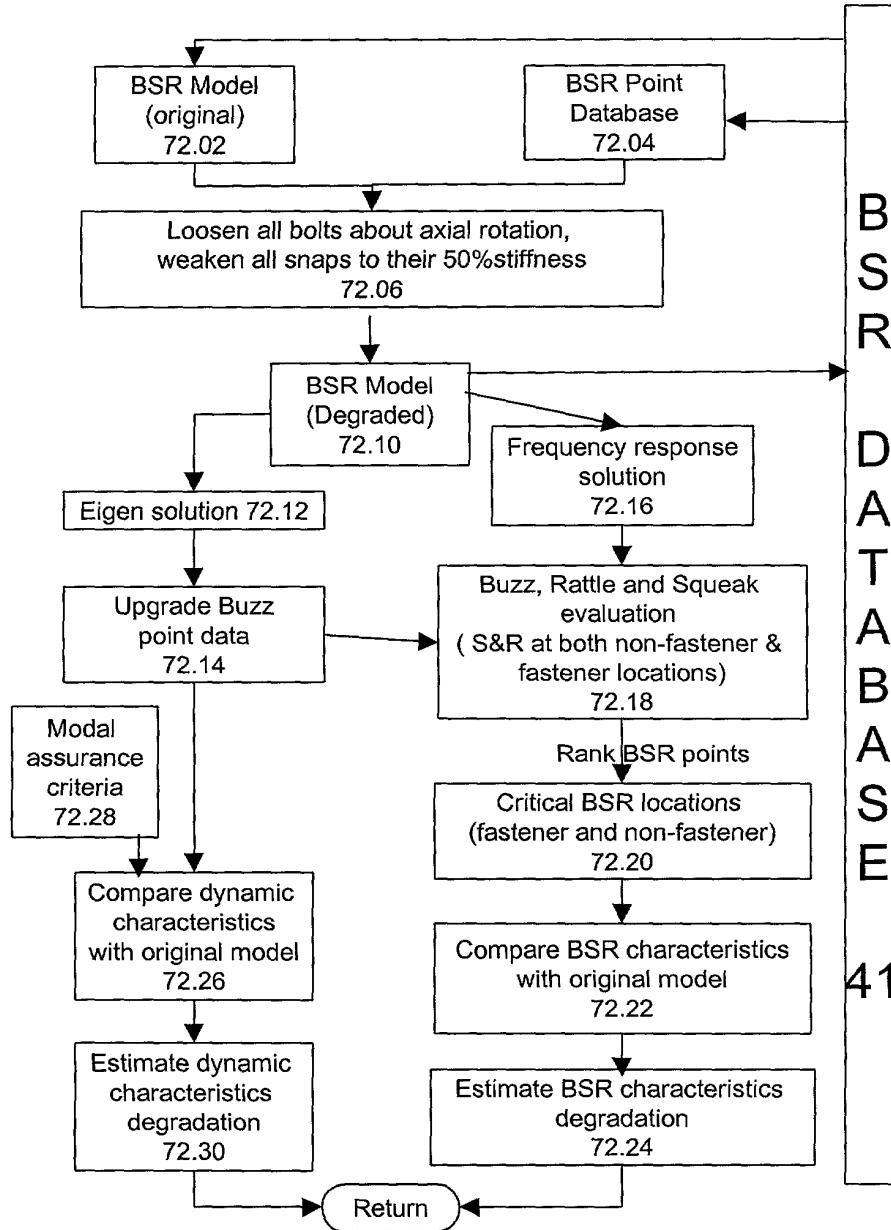
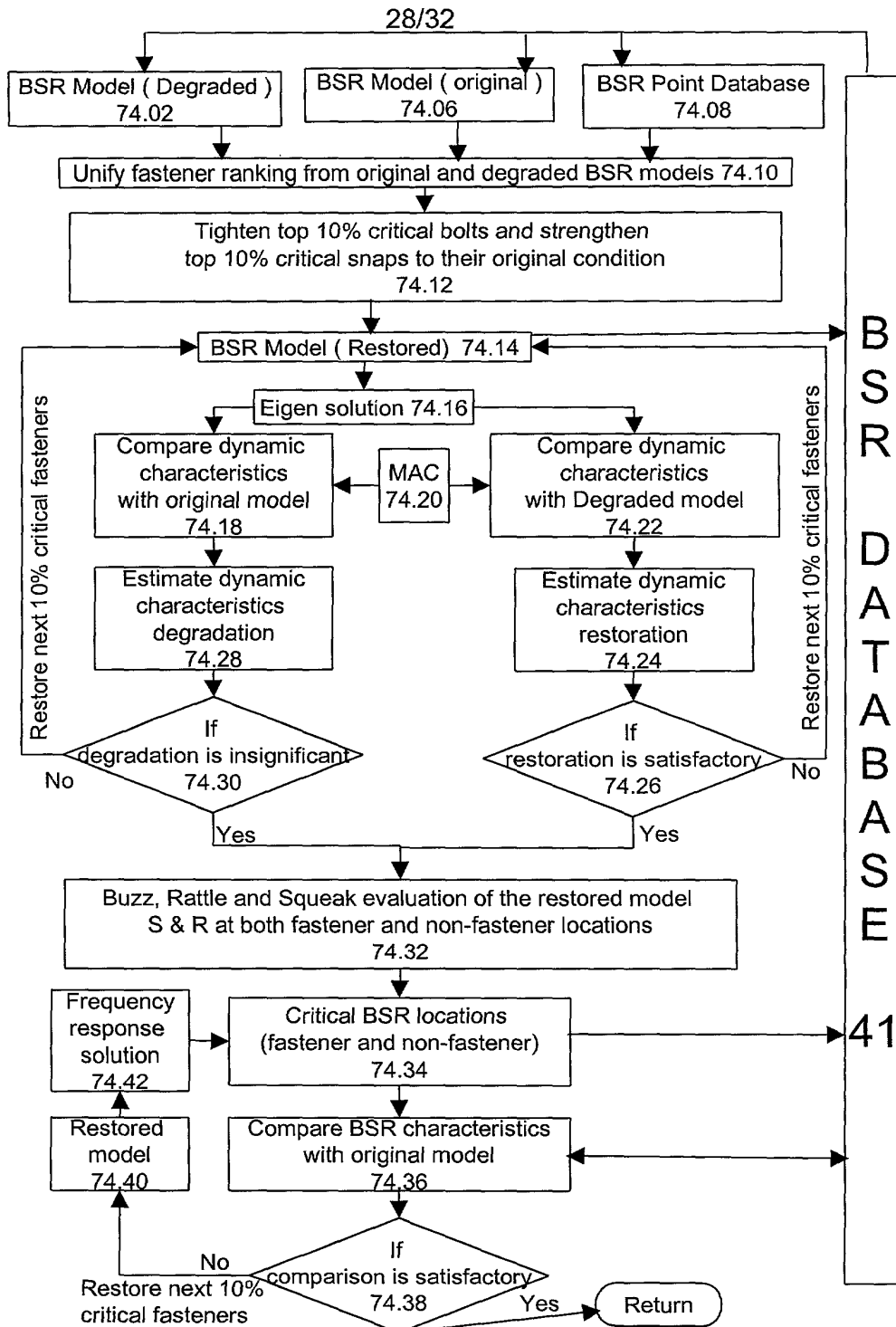
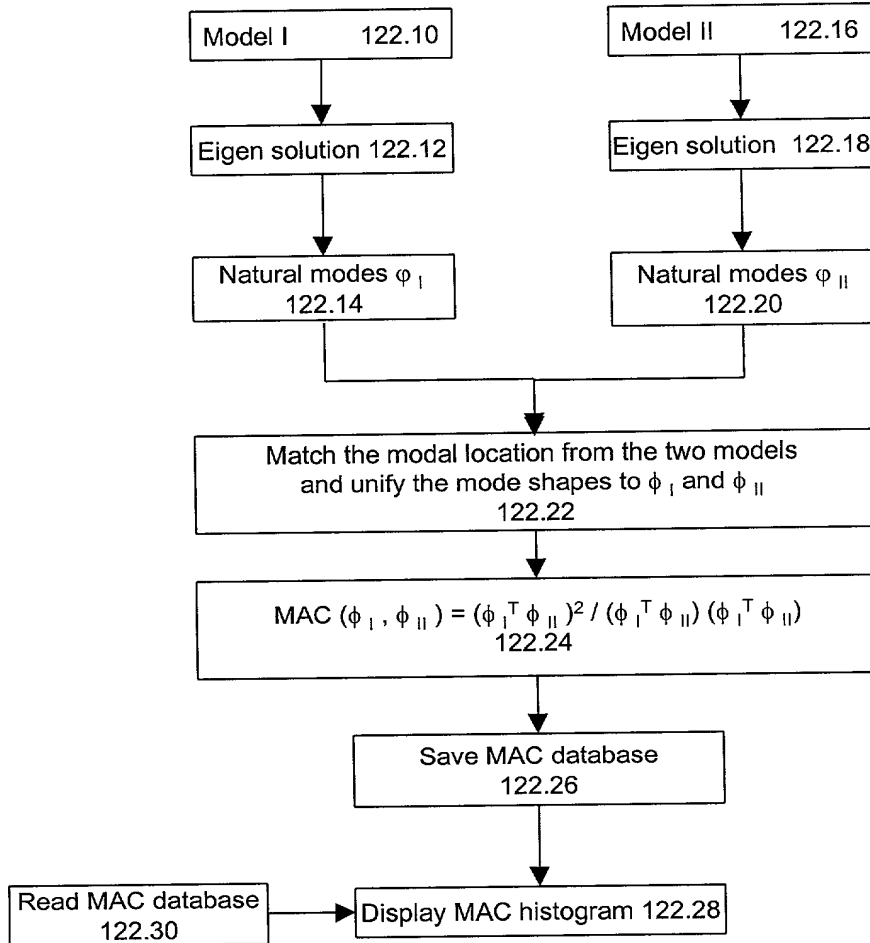


Fig. 20



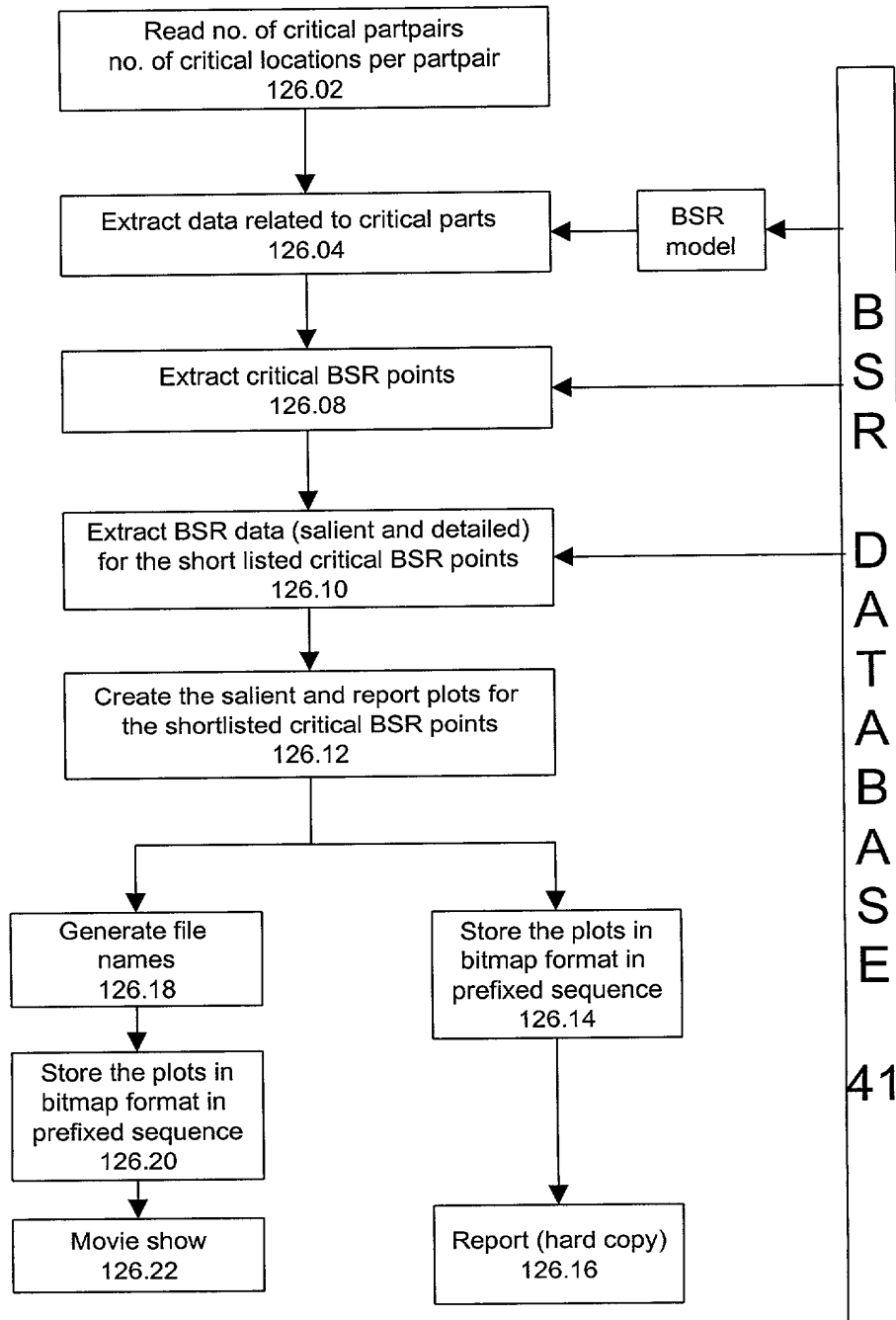
**Fig. 21**



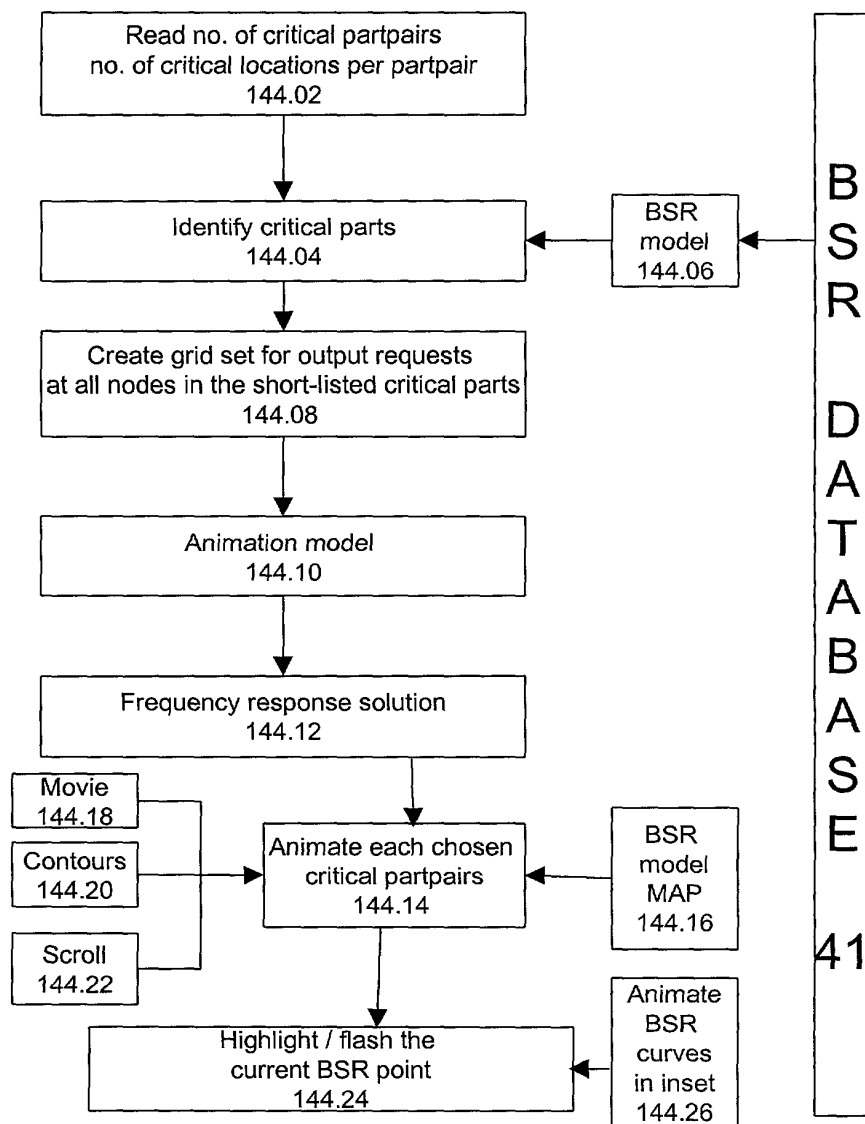
**Ref :** Kenneth F. Alvin, " Robust model error localization for damage detection and finite element model update" structure dynamics and vibration control department , Scandi National Laboratories, A'lbuquerque, NM.

**Fig. 22**

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**Fig. 23**

**Fig. 24**

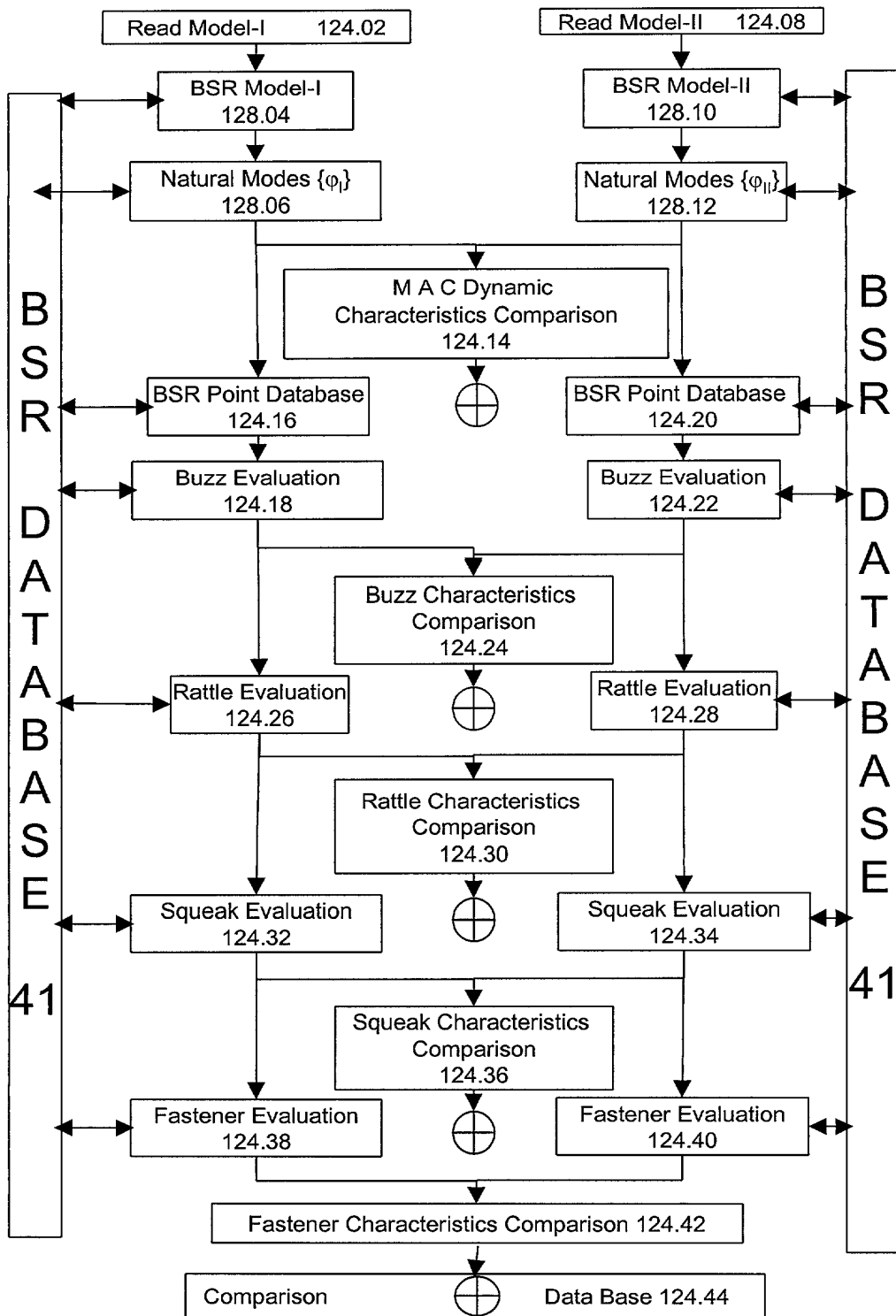


Fig. 25